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3D Numerical Simulation of Tectonic Stress Field and Naturally Fracture System of QING-1 Member in Songliao Basin

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Tectonic stress field and naturally fracture system play a significant role in the exploration and production of unconventional resources like shale oil and gas. However, traditional methods of simulation both of them are very difficult due to lack of substantial field data, such as seismic attributes, well logs, core description, etc.

When doing research on shale oil in Songliao Basin, a numerical method based on finite element model (FEM) integrating with the sequential Gaussian approach is used to overcome the discontinuity of the field data successfully, and successfully predict the distribution and density of tectonic fractures for the QING-1 Member quantitatively (Ding et al., 1998).

The first step of the method is to predict and model 3D parameter field of rock mechanics. Traditional 3D FEM method simulating stress field always has low degree fitting between geometry models and the structure of the study formations. Besides, the several mechanics parameters of the rock can't adequately reflect the heterogeneity. This time, A Petrel-ANSYS technique is applied to solve these problems perfectly. After building a fine geological Petrel model, rock mechanics parameters' curve obtained by known and limited conventional log materials is taken as inputs of hard data, while seismic attribute data body and the experiment test data are taken as constraint of soft data (Zhang et al., 2012). By simulating stochastically through optimizing algorithm of sequential Gaussian simulation, the 3D data field of rock mechanics parameter of the basin is obtained (Fig.1).

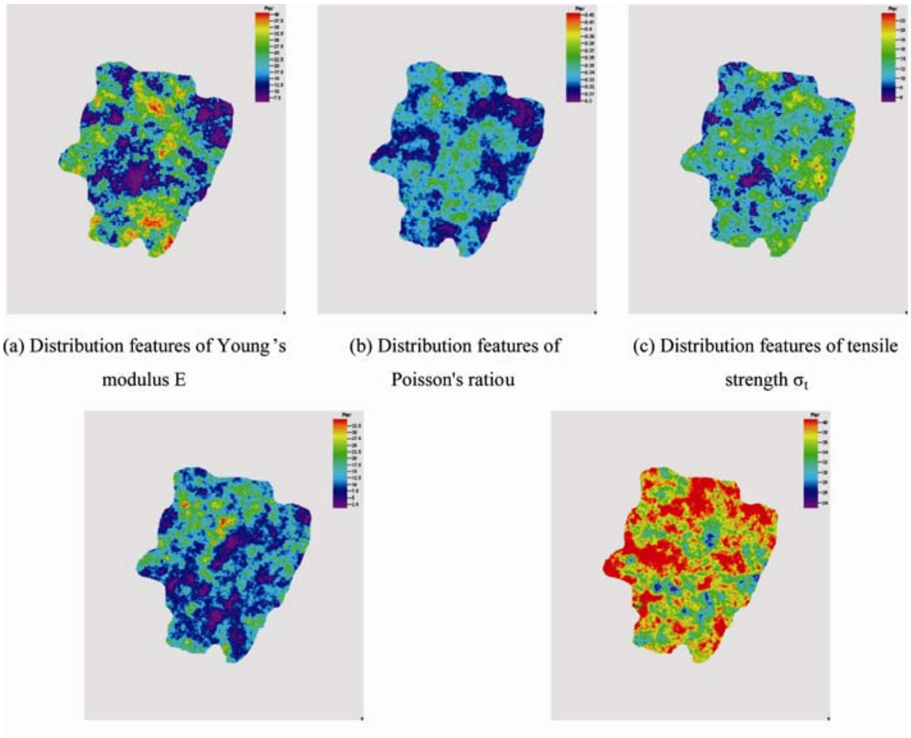
(a) Distribution features of Young's modulus E
(b) Distribution features of Poisson's ratiou
(c) Distribution features of tensile strength σ_t
(d) Distribution features of Cohesion C
(e) Distribution features of internal friction angle φ

Fig. 1. The characteristics of 3-D rock mechanism distribution

The next step is to use FEM to simulate the paleo-stress field of fracturing. Initially, transfer the geological Petrel model and rock mechanics parameter field fully into the ANSYS model, then mesh the model reasonably(Zhao et al., 2009). After that, boundary conditions will be imposed to calculate the stress field, if the result doesn't satisfy the constraint conditions, another realization will be carried out until the total field stress system is met (Fig.2).

The last step is to model naturally fracture system. After paleo -stress field stimulation, stress tensor values and azimuths can be calculated for each node based on the deformation history of the model (Fig.3). Further, Mohr-Coulomb and Griffith fracture criterions will be used to calculate the rate formation of fractures for each node along with fracture azimuth, both of which will be used as inputted data for the next stochastic simulations(Price et al., 1996). Then the sequential Gaussian simulation is applied to generate naturally fracture network with field data as constraint data. Finally, maps of 3D stress field and 3D visual fracture

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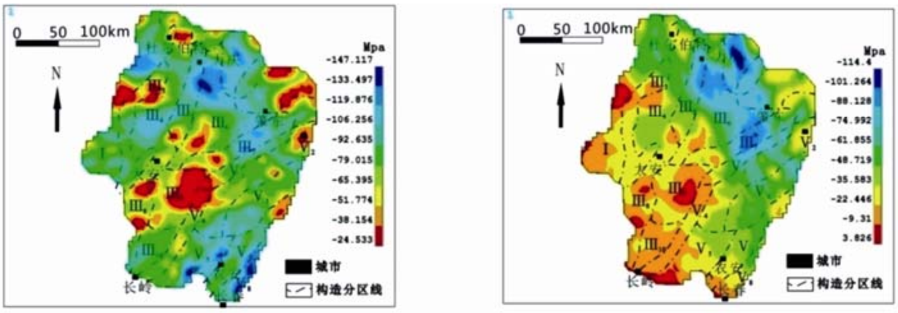
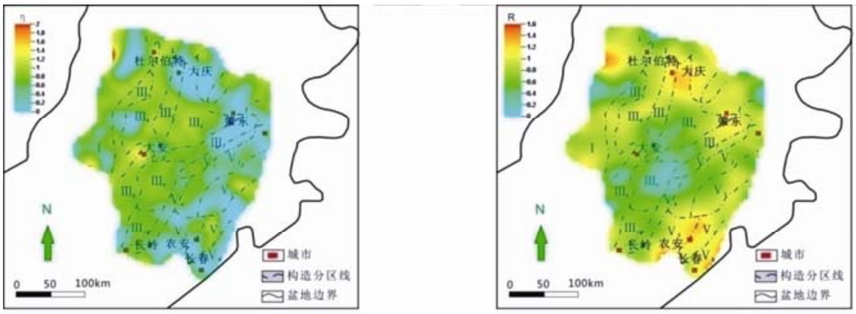
Table 1 The error between the predictive density and that derived from cores

Well Name	Core density(fractures/m)	Predictive density(fractures/m)	Absolute error(fractures/m)	Relative error /%
Hei 52	0.0849	0.0700	0.0149	17.56
Hei 57	0.0088	0.0100	0.0012	15.00
Hei 62	0.0719	0.0500	0.0219	30.42
Hei 68	0.0408	0.0380	0.0028	6.90
Hai 7	0.0104	0.0130	0.0026	24.80



(a) The distribution of the maximum principal stress (b) The distribution of the minimum principal stress

Fig. 2. The results of the numerical simulation of tectonic stress field of the QING-1 Member in Songliao Basin



(a) Tensile fracture rate η contour map (b) Shear fracture rate R contour map

Fig. 3. The contour map of tensile fracture rate and shear fracture rate of the first member of QING-1

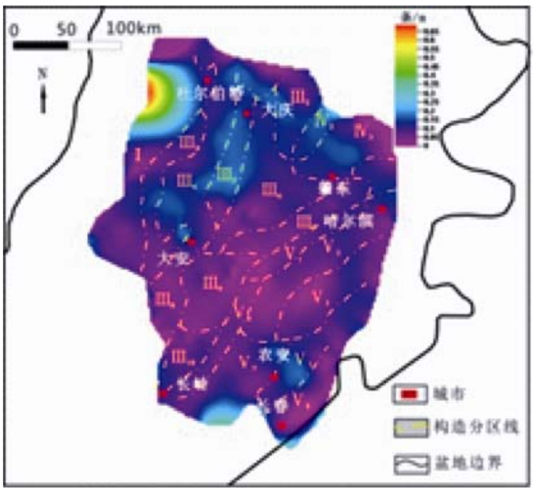


Fig. 4. Predicted shale fracture density of the first member of QING-1 Member in Songliao Basin

network can be obtained (Fig.4).

Compared with the core data, the average error of the simulation results is less 20%(Liu et al., 2009)（Table 1）, which indicates a good correlation between the stimulated data and field data.

Keywords: tectonic stress field,fracture system, finite element, numerical stimulation

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